Report from the Information Needs Working Group

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INTRODUCTION

The goal of this working group was to make recommendations on how information needs can be met in support of recovery efforts and effective management of the corals *Acropora palmata* and *Acropora cervicornis*. These recommendations focus on the need to identify and quantify critical habitat, to quantify the current and historical extents of these species, to identify changes that have occurred over time in biological and geological time frames, and to determine the stability of their populations and the factors that influence this stability. Specific questions are addressed within four topical areas: A) remote sensing, aerial photography and geographic information systems (GIS); B) historical/geological questions and studies; C) strategies to enhance recovery; and D) research and monitoring needs.

1. Remote Sensing, Aerial Photography, and Geographic Information Systems (GIS).

A. *What types of information can we get on critical habitat, historical distribution and extent of Acroporid populations, and on the nature of their declines?*

We are concerned with critical habitat in several senses. First, we must identify and map the habitats that currently include living *Acropora*, and those that have done so in the recent past. It is likely that these will include most of the area that can potentially be colonized by *Acropora*. Further, in case one or more species of Caribbean *Acropora* are to be included on the U.S. Endangered Species Act, the capacity must exist for people to identify key areas of current *Acropora* growth, and to identify associated habitats on land and sea, that provide critical ecological links (adjacent forested watersheds, salt ponds, mangrove and sea grass communities, etc.), whose protection would be essential in conserving those key coral reefs.

In all cases, we need to gather together existing maps of current and historical *Acropora* distributions, as well as maps with a broad range of information from which potential *Acropora* habitats can be inferred, including maps of bathymetry, water quality, physical oceanography, and substrate type. These should be made available within a GIS system in order to facilitate quantitative inferences and overlay analysis as well as to provide access to the information to a wide audience. Local experts should be consulted, and data added from the presentations of the workshop participants and other sources to facilitate the inference process. Where feasible, layers should be incorporated into the GIS representing *Acropora* distributions as reported over time.

In light of the temporal and logistical constraints imposed, to assist with the process of identifying existing *Acropora* habitats, researchers will need to use existing aerial photography in conjunction with existing and new ground truth data. The availability of aerial photographs is very patchy throughout the region. There are some areas in which coral reefs have been mapped with multi- and hyperspectral data from air borne sensors, particularly in U.S. waters. In some areas of the Caribbean, very little mapping of coral reefs exists. For such areas, satellite mapping may be helpful. However, this would best be undertaken by groups that are already engaged in broad area reef mapping work, as experience at that scale is crucial in accurate data interpretation. In all cases, canvassing of local experts can be used to minimize the need for detailed ground-truthing and to provide supplemental information.

Resolution: ***There is a need to compile existing maps, historical and current aerial photographs, bathymetric information, airborne sensor data, and other types of information showing existing and potential Acropora habitats and associated terrestrial and marine habitats essential to the conservation of Acroporids. These data should be incorporated into a GIS database to delineate critical habitat and design appropriate conservation strategies to protect these areas. While a good deal of recent information is available from U.S. locations, there is a need for ground truthing of maps and improved resolution of maps as well as a need for expanded mapping efforts in non-U.S. locations.***

B. *What are the comparative advantages and limitations of the sensor-based mapping tools currently available?*

The major options for sensor-based reef mapping currently are satellite data, aerial photographs, airborne multi- and hyperspectral data, and acoustic data from watercraft. Additionally, airborne laser systems such as LIDAR can be used to provide high-resolution bathymetric information which, when used with other airborne sensor data, can provide extremely useful information on the distribution of ecological communities associated with coral reefs. The LIDAR and hyperspectral options are expensive in terms of initial investment. However, they are ultimately cost effective in terms of the wide range of purposes to which the data can be put to support effective reef management and conservation. We note, however, that none of the options can thus far reliably distinguish among species of coral in any but exceptional circumstances. The uses and limitations of each approach are listed below:

- Satellite
  - Poor resolution
  - Requires heavy ground-truthing
  - In U.S. waters and sporadically elsewhere
  - Gross area determination
- Aerial photos
  - Higher resolution
  - Intermediate ground-truthing
  - Require geometric correction
  - Require expensive processing and specific expertise
  - Most commonly used
  - Finer scale than satellites
- Multi- and Hyperspectral Airborne
  - Needs significant ground-truthing
  - Primarily used in US waters
- Lidar
  - Provides primarily depth information.
  - Best used in conjunction with other airborne data.
- Acoustic Mapping
  - Can establish coral presence/absence
  - Still in development

Resolution: ***While sensor-based reef mapping technologies can provide high resolution information on the distribution of ecological communities, current technology does not provide a reliable tool to distinguish among species of corals or condition (live, dead or diseased or bleached colonies). Thus, the use of sensor-based mapping tools must be combined with underwater visual, video, and photographic monitoring and assessment.***

2. Historical/Geological Questions and Studies

A. *How have populations of these corals changed over the last 10,000 years?*

Ecological observations suggest *Acropora* populations fluctuate on small scales of time and space. Location-specific cores and outcrops have revealed no evidence of population declines similar to that currently underway in at least the last 2500 years (late Holocene), at least in those sites. However, in parts of Florida and the USVI it appears that there have been gaps in the record. For instance, limited coring off Buck Island USVI suggests that the reef community was dominated by *Acropora palmata* over the last 7000 years, but it disappears from the reef system 3000 ybp and then reestablishes after nearly a 1000 year hiatus. There are suggestions that this is part of a regional pattern that is not explained by sea level changes or local oceanographic conditions. The occurrence of this event argues for a regional cause, such as a widespread outbreak of disease, yet this cannot be confirmed at this time.

Previous interruptions in growth were followed by recovery. However, this does not imply that we can necessarily expect recovery from the current population decline, because anthropogenic stresses are currently exacerbating the problem.

Resolution: ***There is a need for larger, regional scale coring programs to compile a long-term record and compare this to present day changes.***

B. *How well can we identify the causative agents for declines in the populations of Acropora?*

Plausible scenarios for some past, localized interruptions in *Acropora* growth can be inferred from considerations of local changes in sea level and antecedent topography. In other cases, the cause cannot be easily identified from those considerations. Further research on present day *Acropora* populations might potentially provide a basis for determining causes of past declines in their populations from evidence preserved in the geochemistry or in the composition and nature of the fossil assemblage. It is imperative to improve our understanding of the nature of the recent declines in *Acropora* populations throughout the Caribbean (white-band disease, predation by mobile fauna, hyper and hypo-thermic stress, land based sources of pollution, and others including interactions of natural and human induced stresses). In particular, we need to have a better understanding of the causes, mechanisms, and epizootiology of coral disease.

Resolution: ***We need to improve our understanding of the nature of recent regional declines in Acropora populations, and whether evidence for causes of past declines are preserved in the geochemistry of Acropora fossils to determine whether the observed decline is part of a natural cyclical process for which natural recovery is likely, or whether anthropogenic stressors have exacerbated these processes and may inhibit recovery.***

C. *What is the extent of existing geological information on Acropora and what should be recommended for further research?*

Current geological information relevant to *Acropora* is mostly location-specific. A complete geological picture of past occurrences would require core and outcrop sampling of Holocene deposits throughout its range at multiple spatial scales; these samples should be dated at a high resolution.

3. Strategies to Enhance Recovery

A. *What are the practical issues involved in the restoration of Acropora populations, including the potential usefulness of propagation and transplantation?*

The goals of mitigation or restoration must be established (e.g., how much should Acroporid cover be increased?) prior to any action. Eliminating or reducing the known anthropogenic causes of declines (including sedimentation, pollution, eutrophication, global warming, over fishing, ship groundings, etc.) is a prerequisite to restoration. Similarly, a greater understanding of causes and consequences of coral disease (white-band, white pox, and other emerging disease) is essential.

Resolution: ***Reef restoration at any scale will have, at best, very limited success unless the causes of decline are understood and action is taken to reduce these threats.***

Transplantation and propagation could enhance populations or limit further declines in small scales (e.g., ship grounding scars) due to the importance of fragmentation as a means of reproduction in *Acropora* species. However, it is important to avoid reducing natural genetic variability and altering the degree of local adaptation in subpopulations. Thus, we need information on the genetic structure of *Acropora* subpopulations and maps of previous distributions. This information should be used in selecting colonies for transplantation and in developing propagation programs. There is a high cost associated with applying these methods at large scales. These costs should be weighed against potential benefits, probability of long-term success, and other management options. Because of the complexity of reef ecology, there will always be a high level of uncertainty involved in any such management interventions. Any restoration options necessitate an adaptive management approach, with the understanding that each intervention is to be treated as an experiment and the intervention adjusted over time in response to periodic evaluations of the success or failure.

Resolution: ***Transplantation and propagation of Acropora colonies is a viable tool to enhance recovery at local scales, but considerations such as appropriate selection of colonies and fragments, the potential effects on genetic structure of populations, and the potential benefits must be weighed against the probability of natural recovery, other management interventions, and likelihood of long-term success.***

B. What is the potential usefulness of enhancing sexual reproduction and recruitment in Acropora?

Improving sexual reproduction and the recruitment of sexually produced planulae would require a greater understanding of the biology of *Acropora* species, with emphasis on the factors involved in determining the natural balance between asexual and sexual reproduction, and the cues involved in the settlement of planulae. More work is needed on demographic modeling to predict response of populations to future disturbances and stresses, and this should encompass a range of spatial and temporal scales.

Resolution: ***Efforts to enhance sexual recruitment may provide a useful tool to promote recovery of populations, but additional research is needed to understand different aspects of sexual reproduction, including basic information on reproductive biology, role of water circulation in transport of larvae, and larval settlement requirements.***

C. What other strategies should be considered to enhance the recovery of Acropora populations?

There are initial efforts to redistribute and propagate *Diadema* sea urchins so as to enhance herbivory in areas where *Acropora* settlement may be hampered by high densities of macroalgae. As with any such interventions, these efforts should include studies of the genetic variability and subpopulation structure of the sea urchin, and the operations should be designed to preserve this variability and structure. A variety of other potential strategies are under investigation. Progress on these could be greatly enhanced by a greater understanding of relevant ecological processes (ie. snail predation, damselfish interactions, fireworms).

Resolution: ***Novel ecological restoration efforts, such as strategies to enhance herbivory, reduce predation pressure, eliminate pest species, and mitigate diseases may have benefits on a local scale, but it is critical that these efforts be undertaken using a science-based approach that incorporates efforts to understand ecological processes and potential impacts of human modification of these processes.***

4. Research and monitoring needs

A. What are the needs with respect to the monitoring of Acropora populations, standing colonies, fragments and new recruits?

Assessment, mitigation and restoration activities, including creation of the demographic models discussed above, require monitoring of percent cover of *Acropora* species as well as counts per unit area of the different life stages (colonies, fragments, living coral crusts, and new recruits). Individual colonies at different life stages should be monitored in comparative studies across a range of environmental conditions including anthropogenic stresses. Monitoring should be carried out at multiple spatial scales over the next several decades at time intervals appropriate to the processes being investigated, and sampling design should be based on statistical power analysis. Monitoring should include assessments of abiotic parameters including potential pollutants and other factors that may enhance the decline of *Acropora* populations.

Resolution: ***Greater efforts are needed to monitor and assess Acropora populations at local to regional scales, at time intervals appropriate to the process under investigation, including studies to follow individual colonies at various life stages exposed to different environmental conditions and anthropogenic stressors.***